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GUIDE FOR DRAINAGE OF SMALL FARM AREAS BY PUMPING




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GUIDE FOR DRAINAGE OF SMALL FARM AREAS BY PUMPING

1. General

The data and information contained herein are for use as a guide in the planning of pump drainage for small areas of high value cropland.

Pumps may be used where it is impossible or uneconomical to obtain gravity outlets for drainage. Other sites may have adequate outlets except during periods of prolonged high water. In such cases, it may be possible to install a combination of gravity and pump drainage. A pumping plant can be used also for standby drainage for brief periods. An example of the need for such an installation is where a tile system outlets into a main ditch and high flows would submerge the tile outlet to a point where drainage would be impaired.

Careful planning is required to insure that the installation selected is the most economical. Another important consideration is the annual operating cost, which may outweigh considerations of higher installation cost. Proper planning will include an investigation of these two factors.

A pump drainage system consists of a pump with powerplant, forebay, discharge bay, storage bay (sump), main drainage channel or tile, and collectors. These systems may require allied measures to operate effectively, such as diversion channels to divert upland runoff, additional internal ditches, levees, or tile drains. Diversions frequently are used to prevent entry of upland runoff into the drainage system, thereby reducing the quantity of water to be pumped and the cost of installation and operation. Such diversions usually are designed to carry the runoff from 25-year frequency storms.

A problem related to the drainage of organic soils is surface subsidence. This occurs after the original establishment of the drainage works. As the protecting water table is lowered subsidence begins at a rapid rate, followed in several years at a slower, more uniform rate. Subsidence rates may be several inches a year during the first few years and then reduce to an average of about an inch per year. The early subsidence is caused by consolidation and compaction of the surface soils. The latter rate is largely the result of oxidation of the drained portion of the soil profile.

Subsidence will increase with the depth of organic material above the water table. Subsidence may be reduced by drainage practices that permit the minimum depth of aeration for a particular crop. Burning and wind erosion are other causes of subsidence. Good agronomic practices and water management will retard the first two items while the latter can be almost eliminated. Water may be pumped from the outlet back into the drainage improvements to subirrigate the soil in order to reduce subsidence. This presumes that there is an ample water supply in the outlet channel for this purpose. If not, drainage

by pumping will allow a higher water table to be maintained during periods when the normal level of drainage is not needed.

2. Drainage Plan

Pump drainage involves a continuing cost of operation and maintenance while gravity drainage involves only maintenance. Therefore, it is important in developing a drainage plan that the consideration be given to all factors that could reduce operation costs.

The following are major items which should be considered in design:

- a. Soils.
- b. Crops to be grown.
- c. Determination of degree of drainage needed.
- d. Location of area and number of acres from which runoff is to be pumped.

(Aerial photos provide useful means for accomplishing this.)
- e. Possibility of installing diversions to reduce the drainage area above the pump.
- f. Location of the collection and disposal drains.
- g. Location of an outlet into a natural stream or ditch and its adequacy.
- h. Possibility of gravity drainage into the natural stream or ditch.
- i. Location of a pumping plant, if needed.
- j. Possible power supply.
- k. Dike location, if necessary.
- l. Determination of floodwater level against which protection is desired.

3. Pump Location

The topography of the area to be drained is a principal consideration in the location of the pumping plant. The usual location is the point where the direction of normal gravity flow would intersect the low boundary of the area to be drained. In many instances it may be possible to locate the pump so as to divide the area to be drained into sections with separate mains leading to the pump, in which case

smaller mains may be used. Other conditions may influence the pump location, such as:

- a. Access to power lines or fuel.
- b. Access road for operation and maintenance.
- c. Protection from flooding.
- d. Sump foundation soils.
- e. Storage bay.
- f. Required pumping lift.
- g. Water disposal area.

4. Drainage Coefficients

Drainage by pumping involves removing, within a specified time period, excess water which cannot be disposed of by gravity or temporarily stored. Drainage coefficients will depend on the amount of storage available, including the storage available in the soil and in open channels. Where amounts of seepage and soil storage are uncertain, plans should consider needs for increased capacity at a later date. The drainage coefficient selected should provide for a specific degree of drainage with regard to topography, crop value, and soils.

a. Surface Drainage or Surface and Tile Drainage

Where all internal drainage is by open channel and pumped from the collecting main, experience has shown that removing the equivalent of 1-1/2 inches of runoff from the drainage area in 24 hours is ample for high value crops in the relatively permeable sandy, sandy loam, or organic soils adjoining the Great Lakes. Where local pumping requirements are not established in other areas, good estimates can be established by first determining the interval of protection desired and the 24-hour rainfall intensity for such period. Rainfall to be removed will equal the inches of rainfall from the 24-hour storm less the inches that can be stored in forebay impoundment, channel, and soil profile. Design should be based on at least a 5-year frequency storm for rotated crops and a 10- to 20-year frequency storm for truck crops. Where a pumping plant is installed in combination with tile and open ditches, requirements for open ditch drainage should be used.

b. Subsurface Drainage

Where a tile system outlets into a sealed pumping bay, excluding direct entry of surface water, a coefficient of

3/4 inch in 24 hours for muck, and 1/2 inch for mineral soil may be used. Where surface water is not removed by open ditches to an outlet separate from the pump, a higher coefficient must be provided. Areas in excess of 50 acres of subsurface drainage should be provided with means for disposal of excess surface water by gravity or pumping.

c. Seepage

Seepage may be insignificant in small farm pumping systems. However, it should be considered when the system is located adjacent to rivers, lakes, or large drainage channels. Seepage may vary widely and methods of analysis are difficult. Perhaps the best method of estimating seepage is by the use of a test pit. The rise of water level in a given unit of time should be measured and the data used to determine the seepage rate.

d. Plant Capacity

Maximum pump discharge requirements may be lowered by allowing additional storage in the ditches and pumping bay. The volume of storage must be sufficient to significantly affect pumping rates. Storage may include water impounded in low areas used for hay or other water tolerant crops. The following relation may be used to estimate pump requirements:

Plant Capacity = Maximum discharge minus storage.

A convenient conversion factor is 1 c.f.s. = 449 g.p.m.

Experience has shown that the computed value of tile discharge should be increased by 20 percent to arrive at an adequate pump capacity. The following formula is recommended for pump capacity for tile systems:

$$Q_s = 1.2 \text{ (Design capacity of tile main)}$$

Where Q_s = quantity of subsurface drainage water to be handled.

5. Pumps

The submerged axial flow propeller pump, or screw pump, is suited for farm drainage because of its efficiency at low heads and because impeller submergence makes priming of this type of pump unnecessary.

Propeller pumps are manufactured by many of the larger pump companies and by local machine shops on a limited scale.

The larger companies use careful hydraulic design procedures and produce a pump that is reliable and efficient. Pumps produced by ex-

perienced firms have rating curves developed from actual tests to verify performance.

Shop-built pumps usually fail to incorporate hydraulic refinements and may not be dependable through a range of conditions. Very few small companies have made sufficient tests to develop pump rating curves.

Service personnel should have sufficient basic information on pumps and horsepower requirements to give the farmer a reasonable estimate of need. Preliminary information supplied will serve also as a check on the pump layout offered to the farmer by the supplier. It is recommended that the specific pump and power unit be selected by the pump supplier. The following information should be supplied to the farmer:

- a. Gallons per minute to be pumped.
- b. Maximum and minimum static heads.
- c. Type of power. (Gas, electric or diesel. If electric motor is planned, he must know if single or 3-phase current is available.)
- d. Sump dimensions.

6. Pumping Head

a. Total Dynamic Head

Pump capacities vary as a function of the head and speed with which the pump operates. A pump should operate under the conditions for which it was designed; therefore, the actual operating heads should be determined accurately. The static head is controlled by the layout of the pumping installation.

Total dynamic head is the sum total of the:

- (1) Maximum static head.
- (2) Entrance loss and column friction.
- (3) Friction loss in pipe and fittings.
- (4) Head loss in bends.
- (5) Velocity head at discharge pipe.

b. Maximum Static Head

Maximum static head is the vertical distance in feet

between the free level of the water in the pumping bay when it has been pumped down to the desired elevation and the elevation of the centerline of discharge pipe. With a submerged outlet, this will be to the level of the free surface of the water at the discharge point.

c. Minimum Static Head

Minimum static head is the difference between the water level when the pump is to be started and the level of the pump discharge water. The discharge elevation of the pump will be governed by the necessary height of dike or the elevation of the water at the point of discharge. A submerged outlet may be used to reduce the static head, as compared to that of a free outlet. This will reduce the discharge elevation to the surface of the water in the channel or other body of water into which the pump is to discharge. When pumping over a dike, static head may be reduced by extending the discharge pipe downward, thus taking advantage of the syphon effect. Danger of syphon backflow can be eliminated by installing an automatic gate on the discharge pipe.

d. Entrance and Friction Loss

Entrance and friction losses in a pump vary with size of pump design. The values of these losses should be supplied by the manufacturer.

e. Friction

Friction losses in pipe and fittings are determined when quantity of discharge, type, size, and length of pipe are known. Refer to chapter 11, section 15, National Engineering Handbook.

f. Velocity Head

Velocity head is the equivalent head, in feet, through which the water would have to fall to acquire the same velocity. Velocity head is expressed as:

$$h = \frac{v^2}{2g}$$

The maximum velocity for low lift pumps should not exceed about 12 feet per second. For preliminary estimates, the approximate size of pump may be calculated from the velocity through the pump. Dividing the required pumping rate by the velocity will give the area of the pump intake pipe. It may be computed from the formula:

$$V = \frac{1.408 \times \text{GPM}}{D^2}$$

Where: V = Velocity in feet per second

GPM = Gallons per minute to be pumped

D = Inside diameter of pipe in inches

7. Storage

Adequate temporary storage of water must be provided to prevent excessive starting and stopping of the pump and motor. Storage, as used here, is the storage of water between the start and stop levels of the pump. For pumps powered with electric motors, the reservoir capacity should be designed to keep the pump starting and stopping cycle per hour within the manufacturer's recommendation. The storage of large amounts of water could result in the reduction of pump size and reduce water level fluctuation. For manually operated pumps, storage may make it possible to arrange the pumping schedule to better fit the operator's schedule.

In subsurface drainage, where only tile water will be pumped, a sump may be provided for the outlet of the main and utilized as a pump bay. This is restricted to small areas of drainage due to storage requirements. Additional storage provided in the tile mains and laterals can be used. Consideration should be given to increased tile main size for storage if an adequate sump is impractical.

When water is pumped from open ditches, some storage is provided by the ditch, or ditches which lead to the pump. If land use and topography near the pump permit, a pond can be used for additional storage.

a. Automatic Operation

Generally, automatically operated pumps are powered by electric motors. The operation is controlled by float or solenoid switches which start the motor when the float rises to pre-set maximum level and stops the motor when the float has reached a pre-set minimum level. The motor will start and stop a maximum number of times when the inflow rate is one-half the pump capacity. Under these conditions, the storage bay will fill during the first half of the cycle while the pump is not operating. During the second half of the cycle, the pump then will empty the bay and also pump the inflow during that half of the cycle.

It is recommended that electric motors start and stop not more than eight times per hour. If this maximum number of cycles is used, the motor is operating 3.75 minutes and at

rest 3.75 minutes. The minimum storage needed is for one-half the time of the cycle or 3.75 minutes. Therefore, storage required is equal to the inflow divided by one-half the pump cycle in minutes.

$$\begin{array}{lcl} \text{Pump storage} & = & \frac{\text{GPM inflow} \times 1/2 \text{ the minutes per cycle}}{\text{in cu. ft.} \quad 2 \text{ (half flow)} \times 7.5 \text{ gal. per cu. ft.}} \end{array}$$

For an 8-minute cycle:

$$\begin{array}{lcl} \text{Pump storage} & = & \frac{\text{Inflow in GPM}}{\text{in cu. ft.} \quad 8/2} = \frac{\text{Inflow in GPM}}{4} \end{array}$$

Example:

Given:

$$\text{Maximum inflow} = 900 \text{ GPM}$$

$$\text{Pump capacity} = 900 \text{ GPM}$$

$$\text{Cycles per hour} = 8$$

$$\text{Minutes per cycle} = 7.5$$

$$\frac{900 \times 3.75}{2 \times 7.5} = 225 \text{ cu. ft. storage,} \\ \text{or 1687.5 gallons}$$

This volume will be filled in the first half of the cycle, or in 3.75 minutes. Adding the 1687.5 gallons which will flow in the second 3.75 minutes of the cycle, the total will give 3375 gallons. This volume pumped in 3.75 minutes will require pumping at the rate of 900 GPM.

b. Manual Operation

Gasoline or diesel pumps usually are manually started. A switch may be installed to stop them at a predetermined low water level. The storage required for manual pump operation will depend upon the time which the operator can spend in operation of the pump. The designer will be required to adapt the amount of storage with the number of cycles per day that the pump will be operated. Generally, two 12-hour cycles per day fit the schedule best. Based on two 12-hour cycles per day, the formula for required storage in channel and pump may be derived as follows:

$$\begin{array}{lcl} \text{Pump storage} & = & \frac{\text{Inflow in GPM}}{\text{in cu. ft.} \quad 2 \times 7.5 \text{ gal. per cu. ft.}} \times \frac{\text{minutes per}}{1/2 \text{ cycle}} \end{array}$$

or

$$\begin{array}{l} \text{Pump storage} \\ \text{in cu. ft.} \end{array} = \frac{\text{Inflow} \times 360}{2 \times 7.5} = \text{Inflow} \times 24$$

Since pump capacity should be equal to inflow

$$\begin{array}{l} \text{Pump storage} \\ \text{in cu. ft.} \end{array} = \text{Pump capacity in cu. ft.} \times 24$$

8. Pump Bays

Pump bays usually are constructed of concrete, concrete blocks, silo staves, corrugated metal, or metal tanks. The rectangular or square design is suggested. The circular design should be used only on small individual systems involving low discharge. The circular shape at higher velocities may cause rotation of the water in the sump and loss in efficiency of the pump. The foundation of the bay should be stable. Special care should be used in organic soils that the foundation will carry the load of the structure and pump under vibration. Closed bays should be checked for uplift forces. The most severe condition occurs when the bay is pumped down and the surrounding soil is saturated.

An important consideration in the useful life of the pumping plant, when located in organic soils, is the allowance for sufficient depth of the pumping bay to provide for future subsidence of the area drained. This allowance should be from 18 inches to 2 feet, considering the life of the structure to be about 25 years. In some cases, the water will enter the pump bay at right angles to the ditch. The inlet channels should be designed in a manner that will insure that the flow will not be reduced below pump capacity by this change in direction of flow.

The velocity of the water entering the bay should not be greater than 3 feet per second. Higher velocities may cause disruption of the flow patterns into the pump.

The pump bay design should meet Soil Conservation Service structural requirements for site conditions and materials used.

9. Pump Submergence and Clearance

The water must have unrestricted entrance to the pump for maximum efficiency. There must be clearance between the pump intake and the bottom of the suction bay. There also must be clearance between the pump intake and the wall of the bay. Spacing between the pumps is important where more than one pump is used in the same bay. The pump will not operate efficiently when submergence over the intake is small.

Sump wall and floor clearances listed below are based on "D", the diameter of the barrel of the pump intake.

Clearance between suction pipe and bottom of bay	- 1	D
Clearance between suction pipe and side walls	- 1-1/2	D
Clearance between suction pipes	- 5	D
Minimum depth of submergence of suction pipe	- 3	D

SAMPLE CALCULATIONS

FOR PUMPING FROM TILE SYSTEM

Given:

Drainage area	- 30 acres
Organic soil (moderately rapid permeability)	
Drainage coefficient	- 3/4 inch in 24 hours
Cycles per hour	- 6
Invert of tile into pump bay	- El. 91.0
Field level	- El. 96.0
Top of pump bay	- El. 97.0
Pump discharges into open ditch with free outfall	

A systematic tile drainage pattern will be used. There are no open ditches. The quantity of water to be pumped will be:

$$\frac{\text{Area drained} \times \text{gallons per acre inch}}{\text{Hours per day} \times \text{minutes per hour}} \times \text{drainage coefficient}$$

In this example:

$$\text{GPM} = \frac{30 \times 27,200 \text{ (approx.)}}{24 \times 60} \times 3/4 = 425 \text{ GPM}$$

Using the 20 percent allowance for lack of surface drainage, we have

$$425 \times 120 = 510 \text{ GPM (say 500)}$$

Storage is calculated by $\frac{\text{GPM to be pumped}}{1/2 \text{ the number of cycles per hour}}$

$$\text{The required storage will be: } \frac{500}{3} = 167 \text{ cu. ft.}$$

Assume a box 10' x 10' = 100 sq. ft.

Then the required storage divided by the area of the sump will equal the required distance between start and stop points. In this case:

$$\frac{167}{100} = 1.67 \text{ depth of storage (say 1.7')}.$$

Assume start elevation at 91.0, the invert of the tile.

The stop elevation then would be $91.0 - 1.7 = 89.3$.

Allow 0.8' for clearance between the pump intake and the floor of the bay. Assuming an 8-inch pump, the submergence would be 2 feet. Therefore, the bottom of the pump bay would be the elevation of the tile invert minus the pumping range minus submergence minus clearance, or $91.0 - 1.7 - 2 - 0.8 = 86.5$.

The pump turn-on point would be at the invert of the tile, or 91.0, and the shut-off point at 89.3.

The maximum static head will be the difference in elevation between the pump shut-off point and the centerline of the high point of the pump discharge. Assuming free discharge, the centerline of high point of the discharge will be 96.0 The static head will be $96.0 - 89.3 = 6.7$ maximum. The minimum static head will be $96.0 - 91.0 = 5.0$ feet. The pump should deliver 500 GPM at a static head of 5.0 to 6.7 feet.

Calculation for Buoyancy

Assume a footing of 12-inch concrete with #5 reinforcing bars on 12-inch centers both ways and wall thickness of box to be 12 inches. Extend the footing 2 feet outside the base.

Box weight = 484 cu. ft. @ 140 pounds = 67,760 pounds

Footer weight = 256 cu. ft. @ 140 pounds = 35,840 pounds

Total 103,600 pounds

Buoyancy = $10 \times 10 \times 11 = 1,100 \times 62.5 = 68,750$ pounds.
The weight exceeds the buoyancy in this case.

If a steel tank were used and assuming:

6' diameter - 8' high.

Water table 3' below surface.

1' of water in tank at time pumped as low as possible.

Steel 1/4" thickness @ 10 pounds per sq. ft.

Weight of tank = 1792 pounds = 1792 pounds

Weight of 1' of water in bottom of tank = 1176 pounds

Total Down Pressure 2968 pounds

Displaced water by tank immersed 5' = 5880 pounds

Buoyancy = 5880 - 2968 = 2912 pounds

1.5 tons of concrete should be added to the structure to prevent floating. Tanks such as this, which have little weight, should be filled with enough water to prevent flotation. This should be done immediately after installation.

Foundation Pressure

Weight of the concrete bay = 103,600 pounds

Area of base = 256 sq. ft.

Weight per sq. ft. $\frac{103,600}{256}$ = 404 lbs./sq. ft.

This could be a high foundation pressure in organic soil.

SAMPLE CALCULATIONS

FOR PUMPING FROM OPEN DITCH SYSTEM

Given:

Drainage area - 40 acres

Organic soil

Drainage coefficient - 1.25 inches in 24 hours

Cycles per day - 2

Maximum water level in ditch - 86.0

Water level in outlet bay - 90.0

Low water level in ditch - 83.0

Pump discharges into outlet bay with free outfall

No electric power available

Quantity of water to be pumped will be:

$$\frac{40 \times 27,200}{24 \times 60} \times 1.25 = 755 \text{ GPM, or } 1.66 \text{ c.f.s.}$$

Required storage for pump will be:

$$755 \times 24 = 18,120 \text{ cu. ft.}$$

Main ditch is 1,000' long with six laterals 1,600' long. A ditch 3' x 3' with 1.5:1 side slopes on a .003 grade will supply the water to the pump in ample time.

The ditch storage will be 10,600 x 22.5, or 238,500 cu. ft. This will contain 1.64 inches from the 40 acres. Checking to determine the amount of water this system will handle, we have:

Soil will store - 1.5 inches

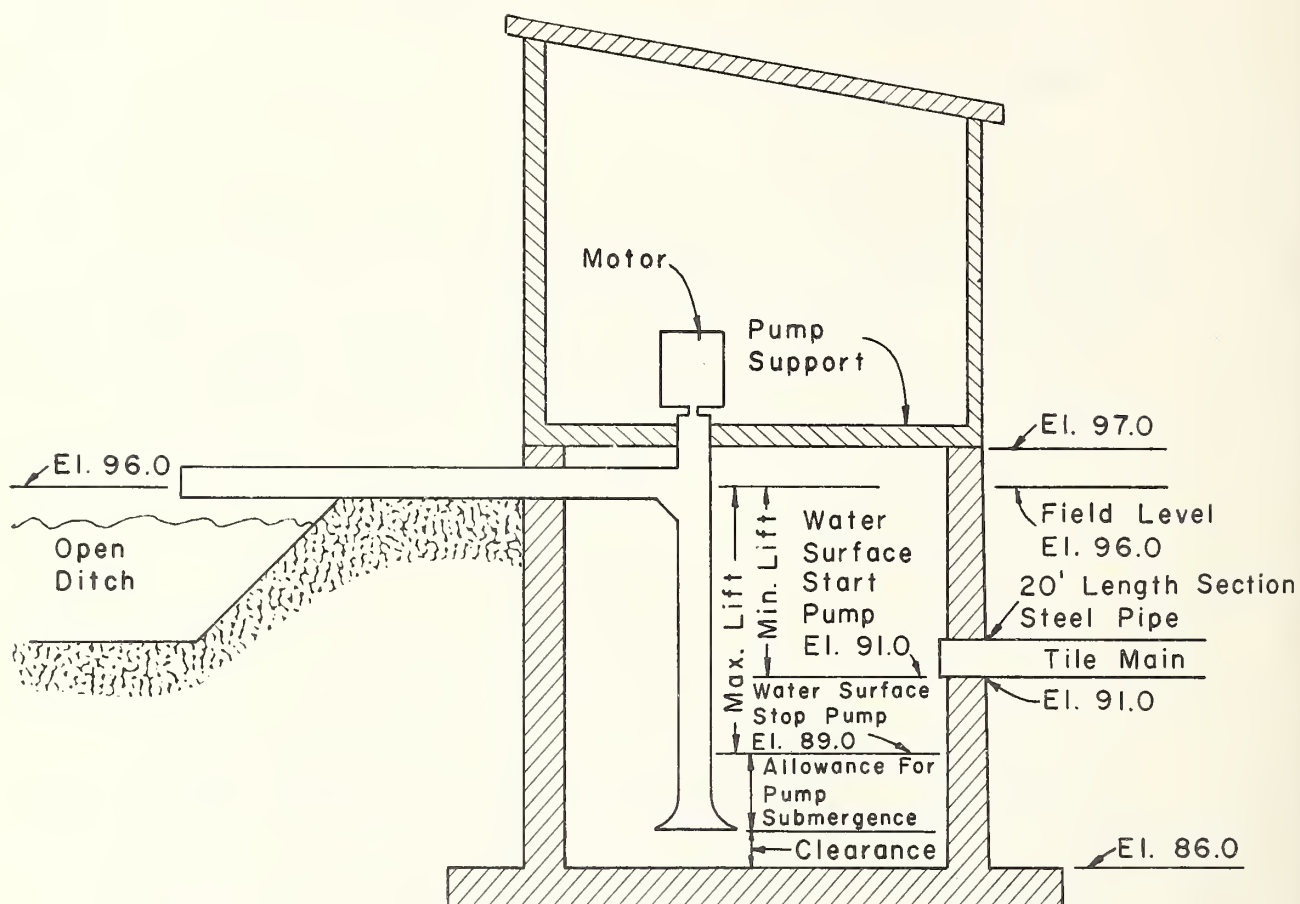
Ditches will store - 1.64 inches

Pump will handle - 1.25 inches

4.39 inches rain

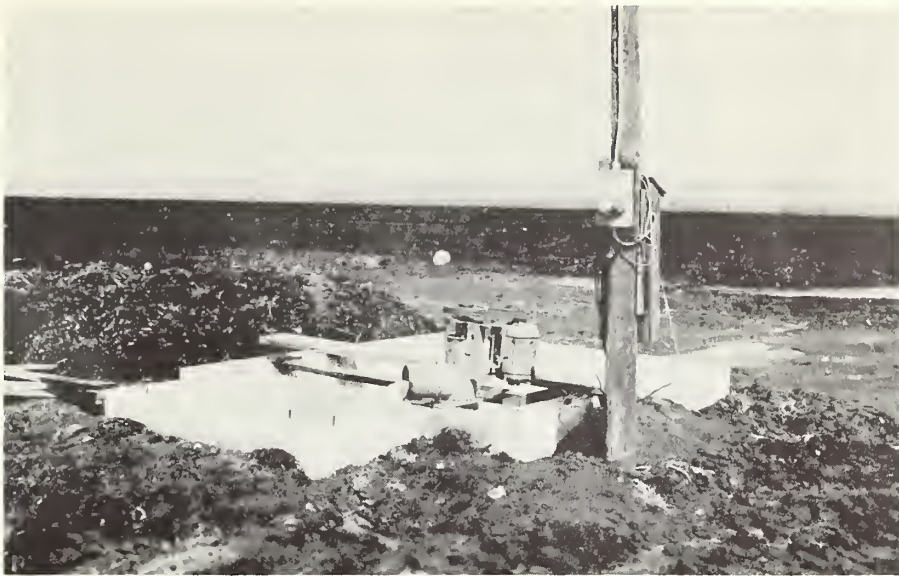
The main is 1,000 feet long with a cross-sectional area of 22.5 sq. ft. This gives 22,500 cu. ft. of storage for the pump while the required storage is 18,120 cu. ft.

The pump required should deliver 755 GPM at a maximum static head of 8 feet and a minimum static head of 5 feet.



TYPICAL PUMP PLANT SET-UP FOR TILE SYSTEM

Figure 1



PUMP PLANT UNDER CONSTRUCTION
(Sump And Pump Installed)

Figure 2



PUMP PLANT UNDER CONSTRUCTION
(Showing Electrode Type Water Level
Starting And Stopping Controls)

Figure 3



PUMP PLANT FOR TILE SYSTEM
(Complete with housing)

Figure 4



SHOP - BUILT PUMP
(15" Pump-Belt Connected - Gas Engine Drive)

Figure 5

